This inconvenience is more than compensated for by the fact that the angular elements of every face, and its relation to another face, can at once be calculated from the symbols of the faces by very easy formulæ. The magnitude of the indices are also shown to be much diminished by using approximations bringing every pole to its place on the sphere of projection within 5 or 6 minutes—an approximation not greater than that constantly used to make observations tally with the calculated symbols.

XXI. "On the Forces concerned in producing the larger Magnetic Disturbances." By BALFOUR STEWART, ESQ., M.A., F.R.S. Received June 14, 1862.

(Abstract).

The author begins by alluding to a previous communication made to the Royal Society, containing an account of the great magnetic storm of August 28–September 7, 1859, in which he had shown that the first effect of this great disturbance was to diminish in intensity both components of the earth's magnetic force at Kew, during a period of about six hours. Such an effect, he argues, can scarcely be supposed due to any combination of earth-currents, of which the period is only a few minutes.

But another appearance is noticeable on the photographic curves which regard the progress of this great disturbance.

While the great wave of force had a period of about six hours, there were superimposed upon it smaller disturbances having a period of a few minutes, and therefore comparable in this respect with earth-currents.

These smaller disturbances are of very frequent occurrence, and show themselves in the Kew magnetograph curves as serrated appearances, occasionally magnified into peaks and hollows.

Two hypotheses may be entertained regarding them.

1st. They may be conceived to represent small and rapid changes in the intensity of the whole disturbing force which acts upon the magnet; and since (as stated above) this force cannot be supposed due to earth-currents, so neither can its variations be caused by these.

2nd. The peaks and hollows may be supposed due to the direct action of earth-currents upon the magnets.

The following argument is advanced to show that the second of these hypotheses is untenable.

Let us compare together the two magnetic disturbances of August and September 1859 and August 1860; and suppose the peaks and hollows of the disturbance curves of these dates to be caused by earth-currents. This would require that currents of the same name should have simultaneously travelled between Margate and Ramsgate, and between Ramsgate and Ashford during the latter disturbance, whereas during the former these currents should have been of different names, that is to say, the one positive and the other negative. According to Mr. Walker's observations however, on both these occasions a current between Margate and Ramsgate was simultaneous with one of the same name between Ramsgate and Ashford.

Thus, if we adopt the second hypothesis, it would appear that these lines ought to have been affected differently on these two occasions, whereas by observation they were affected in the same manner; the conclusion is that this hypothesis does not represent the truth.

The author then shows that earth-currents observed simultaneously with a very abrupt disturbance which commenced about $11^h\ 17^m$ A.M., September 1, 1859, would lead us to infer that the former are induced currents due to sudden and rapid changes in the magnetism of the earth.

Referring now to the first hypothesis, which asserts that the peaks and hollows represent small and rapid changes in the intensity of the whole disturbing force which acts upon the magnet, it would follow that these peaks and hollows should in this case comport themselves with regard to the three elements of the earth's magnetism in the same way as the whole disturbing force of which they represent the changes. Thus, if the tendency of the great body of the disturbing force is to raise the curves for the three elements simultaneously, then a small peak in one element should correspond to a peak, and not to a hollow, in the other two. But if, on the other hand, the tendency of the disturbing force is to raise one of the curves and lower the other two, then a peak in the first should correspond to a hollow in the others.

This is shown to be the case in the disturbances extending from the beginning of 1858 to the end of 1860; and the author therefore

concludes that peaks and hollows represent small and rapid changes in the intensity of the whole disturbing force which acts upon the magnet.

It is then shown that use may be made of these peaks and hollows, if we wish to analyse the forces concerned in producing disturbances. Let us suppose that several independent forces are concerned. It is very unlikely that a small and rapid change takes place at the same instant in more than one of these. The measurement therefore of simultaneous abrupt changes for the three elements may enable us to determine the character of one of the elementary disturbing forces at work.

It is not even necessary to confine ourselves to very rapid changes, provided we take peaks or hollows which present a similar appearance for all the elements, as such can only be produced by the action of a single force.

The author then shows that a peak of the horizontal force always corresponds to a peak of the vertical force, and not to a hollow, and that, when similar peaks are compared together, the horizontal-force peak is always as nearly as possible double in size that of the vertical force.

This curious fact would imply that the resolved portion of the disturbing force which acts in the plane of the magnetic meridian is always in nearly the same direction. The dip of this resolved portion will be about $17\frac{1}{2}^{\circ}$.

It is also found that a declination peak corresponds to a peak of either force, except in the case of the great disturbance of August to September 1859, during the most violent portion of which a peak of the declination corresponded to a hollow in either force. The length, however, of a declination peak does not bear an invariable ratio to that of a force peak—this ratio varying much from one disturbance to another, but not much from one part to another of the same disturbance. In this last case, however, the variation of the ratio, although not great, is yet greater than that of the ratio between the two force peaks; so that it is somewhat difficult to obtain similar peaks when comparing the declination curve with that of either force.

It thus appears that the force which acts upon the magnets does not vary much from one part to another of the same disturbance,

and it therefore becomes possible to give the elements of this force, which will thus characterize the disturbance.

The author then attempts, by means of comparing similar appearances, to represent the force at work for each disturbance between the beginning of 1858 to the end of 1860. The great disturbance of August to September 1859 is here remarkable as one in which two independent disturbing forces seem to have acted at once,—one of these being of the normal type, in which all the elements were raised or depressed together, while in the other the declination was raised when both elements of the force were depressed.

It will be observed that this method of analysis does not completely determine the disturbing force, but merely fixes the line of its resultant action, along which the force itself may be either positive or negative; or, again, there may be two nearly opposite forces acting against one another, the visible disturbance denoting merely the difference in strength between the two; and there is some reason to think that this last supposition represents the true state of the case.

For while the definite relation which exists between the peaks of the two force-components shows that all disturbing forces affect these in nearly the same way, yet sometimes, though very rarely, in the general progress of the curve one of the elements will be above the normal while the other is below it. Now, this may be accounted for in the following manner. Suppose we have a disturbance producing an elevation in the horizontal force represented by $+40$, and one in the vertical force represented by $+20$. This will be of the normal type. Suppose now that at the same time we have another force nearly similar, whose action on the two force-elements is represented by -39 -21. This is also sufficiently near the normal type. The result of these two disturbances superimposed will be $+1$ and -1, showing that the one element is raised above its normal position, while the other is depressed below it. This idea of two opposite forces acting simultaneously in disturbances is that entertained by General Sabine from other considerations.